Technology Opportunity

High-Temperature Polymer Matrix Composites

The National Aeronautics and Space Administration seeks to transfer technology for the development and production of high-strength, high-temperature polymer matrix composite materials.

Potential Commercial Uses

The PMR-15 family of polymers is commercially available and has seen a number of industrial applications, particularly in the aircraft industry where it has been used to replace machined titanium parts in engines for military aircraft. It can be used wherever there is a need for lightweight materials that can sustain temperatures up to 700 °F.

Some examples are

- Ductwork for jet engine applications
- Fan blades
- Automobile engine and exhaust system components
- Self-lubricating bearings for high-temperature use
- Lightweight, nonmetallic ductwork for high temperatures
- Heat-resistant panels
- Lightweight, fire-safe objects and fire barriers

Benefits

- Maximum use temperatures of ~600 °F (~300 °C)
- Stronger than most aluminum alloys at high temperatures
- Lighter than titanium
- Upper use temperature comparable to aluminum and titanium (see fig. 1)
- Higher specific strength than aluminum, titanium, and steel (see fig. 2)
- Moldable to near-net shape, which reduces machining costs
- Properties can be tailored by substituting monomers
- Extremely stiff, lightweight parts in carbon fiber reinforced composites

The Technology

For more than 20 years the NASA Glenn Research Center has been a leader in the development of polymer matrix composite materials for use at high temperature. These Glenn-developed materials have maximum use temperatures that are higher than the

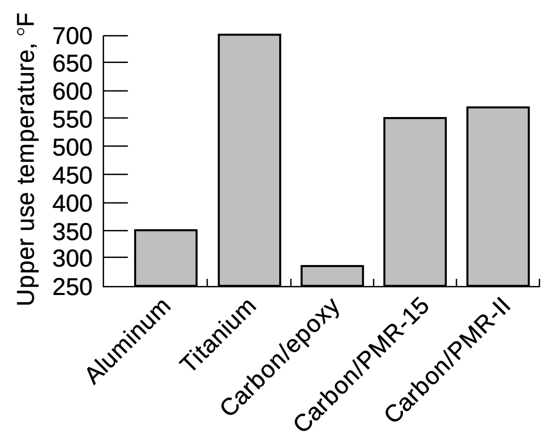

Figure 1.—High-temperature polymer composites have upper use temperatures comparable to aluminum and titanium.

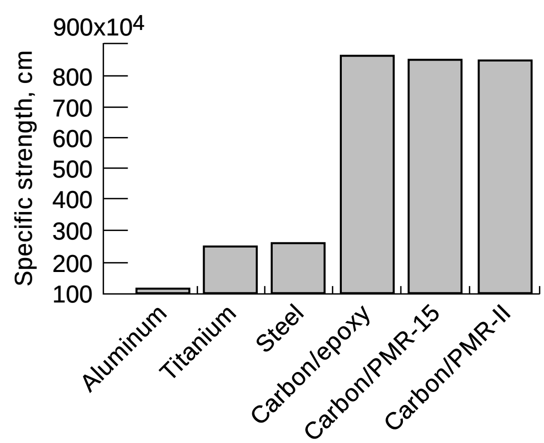

Figure 2.—Carbon fiber/polymer composite materials have high specific strength (strength/density).

more familiar epoxy resins by several hundred degrees Fahrenheit. The processing approach developed at Glenn makes use of two reaction steps, occurring at different temperatures, which allow the residual solvent and the volatile reaction products to escape before final curing of the part. This results in high quality, void-free parts.

Polyimides are well known for their high temperature stability. However, these materials have high softening temperatures and are only soluble in high boiling solvents. In addition, low molecular weight byproducts (typically water or alcohols) are formed during processing. As a result, the processing of void-free polyimide-based composites is often difficult to achieve.

In the early 1970's researchers at NASA Glenn developed the PMR (**P**olymerization of **M**onomer **R**eactants) family of polyimides, in response to an aerospace industry need for processable, high temperature polyimides for use in fiber reinforced composites. The principal resin in this family, PMR-15, has become the industry standard for use in applications which see upper use temperatures between 450 and 550 °F (232 to 288 °C). The current worldwide market for PMR-15 is on the order of 40,000 to 50,000 pounds per year. Graphite fiber reinforced PMR-15 composites are currently in use in both military and commercial aircraft engine components, e.g., the outer bypass duct for the GE F-404, exit flaps for the P&W F-100-229, and the core cowl for the GE/Snecma CF6-80A3. Higher temperature PMR polyimides, e.g., PMR-II-50 and VCAP-75, have been developed for use at temperatures up to 650 to 700 °F (343 to 371 °C).

In the PMR approach, fibers are impregnated with a solution of monomers dissolved in a low boiling solvent, typically methanol. Composites are prepared from these fibers (prepreg) in two separate processing steps. In the first step, the prepreg is heated to between 350 and 450 °F to convert the various monomers into a series of low molecular weight polyimides. These polyimides are end-capped with a reactive group which, in the second processing step, cross-links at temperatures around 550 °F. Melt-flow and processability can be affected by controlling the molecular weight of the polyimides that are formed in the first step of this process. This enables the removal of low molecular weight byproducts (also formed in the first step) thereby minimizing or eliminating void formation in the final cured composite.

Recent research at NASA Glenn has produced more "environmentally friendly" versions of PMR-15, which are based upon non-carcinogenic diamine starting materials. These materials will potentially save the industry millions of dollars in costs associated with the handling and disposal of PMR-15 materials. A NASA Glenn/General Electric/ Fiber Innovations Inc. team recently developed a process to enable the low cost manufacturing of components from PMR-15. This process, designated Solvent Assisted Resin Transfer Molding (SARTM), reduces manufacturing costs for PMR based components by 30% or more over traditional hand lay-up based methods.

Options for Commercialization

PMR-15 is commercially available. NASA researchers are interested in continuing to develop this class of materials with those in industry and academia and are seeking industrial partners to cooperatively develop additional applications for this class of material.

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